IRIDIUM ABUNDANCE MEASUREMENTS ACROSS BIO-EVENT HORIZONS IN THE GEOLOGIC RECORD; C. J. Orth and M. Attrep, Jr., Isotope and Nuclear Chemistry Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Geochemical studies have been performed on thousands of rock samples collected across bio-event horizons in the fossil record using INAA for about 40 common and trace elements and radiochemical isolation procedures for Os, Ir, Pt, and Au on selected samples. These studies were begun soon after the Alvarez team announced their discovery of the K-T Ir anomaly in marine rock sequences in Europe (1,2). With their encouragement we searched for the anomaly in nearby continental (freshwater coal swamp) deposits. In collaboration with scientists from the USGS in Denver we soon located the anomaly and observed that a floral crisis occurred at the same stratigraphic position as the Ir spike (3). Further work in the Raton Basin has turned up numerous well-preserved K-T boundary sections, some with easy access in road cuts along Interstate 25 (4,5).

Although we have continued to study the K-T boundary and provide geochemical measurements for other groups trying to precisely locate it, we turned our primary effort in 1981, following Snowbird I, to examining the other bio-events in the Phanerozoic, especially to those that are older than the terminal Cretaceous. The following horizons have been examined in collaboration with paleontologists and geologists: boundary [country {number of sections}]; Precambrian-Cambrian [Russia {1}, China {3}], Late Cambrian Biomere Boundaries [Utah {3}], Cambrian-Ordovician [Scandinavia {1}], Ordovician-Silurian [Quebec {2}, Scotland {1}], Silurian-Devonian [Czechoslovakia {1}], Frasnian-Famennian [North America {2}, Australia {3}, Morocco {1}, Germany {1}], Devonian-Mississippian [Oklahoma {1}, China {1}], Mississippian-Pennsylvanian [Oklahoma {1}, Texas {3}], Permian-Triassic [China {4}, Austria {1}], Triassic-Jurassic [England {1}, Austria {1}], Late Toarcian [England {1}], Cenomanian-Turonian [North America {15}, England {1}, Spain {1}], Cretaceous-Tertiary [global {>25}], Upper Eocene impact horizons [Atlantic, Caribbean, Pacific and Indian Oceans {6}].

In well preserved sections, the K-T Ir anomaly is at least 10 times and generally 100 times stronger than other Ir concentration peaks we have found in the sedimentary geologic record of the Phanerozoic. Furthermore, under quiet depositional environments with good preservation, the K-T Ir anomaly is sharp and singular. In samples from continental K-T sequences, Os/Ir, Pt/Ir and Au/Ir are quite similar to C1 chondrite ratios. This is not the case for moderate Ir anomalies we have observed in Devonian and Carboniferous marine sequences, where Pt/Ir ranges from 10 to 100 times chondritic; Pt appears to be at least 10 times more abundant in sea water than is Ir. Osmium concentrations depend on the redox character of the rocks; concentrations are generally higher in sediments formed under reducing conditions, and therefore Os/Ir ratios vary tremendously in cases of chemical precipitation.

In response to volcanism arguments from critics of the Alvarez impact hypothesis, hundreds of samples from altered volcanic ash beds (bentonites) have been analyzed and beds from Plinian (silicic) eruptions contain very low concentrations of Pt-group elements and other siderophiles (Ir $<$ 0.030 ppb). Tholeiitic lava from recent eruptions on Hawaii (hot-spot volcanism) contains 0.3 to 0.4 ppb of Ir and a small fraction escapes in the vapor phase from the magma (6). Ultramafic rocks from the upper mantle (kimberlites and lamproites) contain relatively high concentrations of Pt-group elements. Arguments that favor Deccan Traps volcanism as the source of the excess K-T Ir are unfounded; samples from Deccan basalts contain negligible Ir ( < 0.026 ppb). Although eruptive processes were active across the K-T boundary, they could not provide the global Ir anomaly and occurrence of shocked mineral grains. However, excess amounts of chalcophiles (As, Se, and Sb) at the boundary might have resulted from deep-source volcanism as a result of crustal excavation and rupture from the impact.

Thus far, our evidence, with the exception of the two or three Late Eocene impact horizons, does not support recent hypotheses (7-9) which suggest that impacts from cyclic swarms of comets in the inner Solar System were responsible for the periodic mass extinctions reported by Raup and Sepkoski (10). However, much more work needs to be done to resolve the problem, especially tedious searching for shocked grains, because some comet impacts might provide little or no excess Ir. For instance, melt rock from numerous terrestrial impact structures contains no measureable enhancement of Ir over that of the target rocks.

Although we have found moderate Ir (Pt-group) anomalies at the Frasnian-Famennian (F-F) in Australia and Morocco (11), in the lower Mississippian of Oklahoma (12), at the Mississippian-Pennsylvanian of Oklahoma and Texas (13), and at the Cenomanian-Turonian in the Western Interior of North America (14), the excess Ir and other elements appear to have resulted from terrestrial processes (bacterial, upwelling, precipitation in anoxic basins, and deep-source eruptive processes). The combination of the massive impact and abrupt extinction of some planktonic and floral taxa at the K-T boundary appears to be unique in the Phanerozoic, which leads us to believe that the bolide might have been larger/faster than previously estimated.

References:

(1) Alvarez, W., Alvarez, L.W., Asaro, F., and Michel, H.V., 1979, EOS 60, 734.
(2) Alvarez, L.W., Alvarez, W., Asaro, F., and Michel, H.V., 1980, Science 208, 921-1108.
(3) Orth, C.J., Gilmore, J.S., Knight, J.D., Pillmore, C.L., Tschudy, R.H., and Fassett, J.E., 1981, Science 214, 1341-1343.
(4) Gilmore, J.S., Knight, J.D., Orth, C.J., Pillmore, C.L., and Tschudy, R.H., 1984, Nature 307, 224-228.
(5) Pillmore, C.L., Tschudy, R.H., Orth, C.J., Gilmore, J.S., and Knight, J.D., 1984, Science 223, 1180-1183.
(6) Zoller, W.H., Parrington, J.R., and Phelan Korta, J.M., 1983, Science 222, 1118-1121.
(7) Rampino, M.R. and Stothers, R.B., 1984, Nature 308, 709-712.
(8) Whitmire, D.P. and Jackson, A.A., 1984, ibid, 713-714.
(9) Davis, M., Hut, P., and Muller, R.A., 1984, ibid, 715-717.
(10) Raup, D.M. and Sepkoski, J.J., Jr., 1984, Proc. Natl. Acad. Sci. 81, 801-805.
(11) Playford, P.E., McLaren, D.J., Orth, C.J., Gilmore, J.S., and Goodfellow, W.D., 1984, Science 226, 437-439.
(12) Orth, C.J., Quintana, L.R., Gilmore, J.S., Barrick, J.E., Haywa, J.N., and Spesshardt, S.A., 1988, Geology, in press.
(13) Orth, C.J., Quintana, L.R., Gilmore, J.S., Grayson R.C., Jr., and Westergaard, E.H., 1986, Geology 14, 986-990.
(14) Orth, C.J., Attrep, M., Jr., Mao, X.Y., Kauffman, E.G., Diner, R., and Elder, W.P., 1988, Geophys. Res. Lett. 15, 346-349.